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Letter of Intent

Test of Electron/Hadron Compensation for Warm Liquid Calorimetry

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Introduction

In the 1989 fixed target run at Fermilab we wish to test a sampling hadron calorimeter using 2,2,4,4-tetramethyl pentane ("TMP") as the active medium. The main objective of the test is to identify one or more combinations of plate composition, plate thickness, and electric field that will produce near equality in hadron and electron response, as predicted by Wigmans [1]. This test is part of a broader program, "Fast Hermetic Calorimetry Using Warm Liquids: Proposal for Generic Detector R&D for the SSC/LHC" [2], which is being supported by the U.S. DOE and by IN2P3 and CEA in France. This proposal is attached as Appendix A.

Motivation

Use of a liquid medium like TMS (or TMP with very high fields) could lead to an SSC/LHC calorimeter with performance that is superior to what is possible with liquid argon. There are two central arguments. First, warm liquid modules can be smaller, with thinner boundaries made of single walls with braces bathed in the liquid. We expect calorimeters taking advantage of these possibilities to be much more hermetic than has been possible for cryogenic devices. Second, many hybrid preamps with large total heat dissipation can be placed inside or immediately outside the liquid modules. Then gap, cable, and preamp capacitance can be chosen to optimize the signal-to-noise for fast response. Other advantages include (predicted) equal electron/hadron response without use of uranium plates, reduced dependence of gain on gap thickness, and fast charge collection.

Generic R&D program

The objectives of our SSC/LHC detector R&D program [2] are:

(1) to measure properties of hydrogenous warm liquid ionization media (TMS and TMP) relevant for calorimetry at SSC/LHC, such as saturation effects from heavily ionizing particles, and effects of high instantaneous beam rates and electric field, as well as studies of materials to be used with such liquids, compatible with the needed liquid purity;

(2) to measure the electron/hadron response and energy resolution achievable with these liquids, as a function of absorber composition, sampling fraction, and electric field;

(3) to design a warm-liquid calorimeter module that meets safety, hermeticity, and time-resolution requirements for SSC/LHC use;

(4) to construct and test a prototype hadron/electron calorimeter based on that design.

Our present funding support is for objectives (1), (2), and (3), which are being pursued in parallel. This Letter of Intent is for test beam work directed primarily toward objective (2), although it will benefit all four objectives.

Measurement of electron/hadron response using TMP

The electron/hadron response (e/h) and fractional energy resolution (dE/E) of TMP in combination with U, Pb, and Fe absorber plates have been calculated by one of us [1]. These calculations are intricate and depend, among other factors, on saturation in the response of these media to slow protons recoiling from spallation neutrons. Not only must this saturation be measured, as we are undertaking to do, but also the predicted dependence of e/h and dE/E on the plate composition, sampling fraction, resolving time, and electric field must be established experimentally. Also, practical calorimeter designs using TMS or TMP will likely require at least two different absorber materials (e.g. Pb with stainless steel to contain the liquid). The effects of composite absorbers are even more important to measure, as they are still more tedious to calculate [1].

In order to save time we will start by using TMP "boxes" similar to production modules for the upgraded UA1 calorimeter [3], in combination with absorber plates that are different from the U plates used by UA1. The primary objective will be to identify a practical combination of materials, thicknesses, sampling fractions, and electric field (e.g. 5 mm of Pb/1.2% Ca/1.1% Sn, 1 mm of stainless steel, 2.5 mm of TMP, 15 KV/cm) that yields acceptable compensation ($|1 - e/h| < 0.07$, contributing less than 1% to dE/E). Using these TMP hadron calorimeter data together with our separate measurements of the saturation properties both of TMP and tetramethyl silane ("TMS") will permit very reliable estimates of the properties of TMS calorimeters with similar absorber configurations.

The TMP will be contained in UA1-type boxes, approximately 20 cm x 60 cm in area. The 20-30 microsecond lifetime already achieved [3] for TMP exceeds the requirements of this test. Each module contains twelve 10 cm x 10 cm anodes that collect ionization electrons from the TMP in each of two 1.25 mm gaps. This transverse segmentation is representative of that encountered in SSC/LHC designs.

We plan to test absorber plates made of combinations of materials that are of practical interest for the SSC/LHC: Fe, Pb, and possibly Sn. The TMP box faces depend for support on the absorber plates, which must be of uniform thickness and able to be squeezed flat. We expect the average absorption length within the test calorimeter to be in the range 20-28 cm. Then >97% transverse containment of hadron showers can be achieved in a 60 cm x 60 cm stack with three boxes per gap. With absorbers as thin as 4 mm per gap to be tested, up to 256 gaps will be needed for a 6-absorption-length calorimeter. (A coarse "leakage" calorimeter will be placed downstream and on the sides if necessary.) Then the maximum number of gaps is 768. For the 1989 test, however, TMP boxes will be place only in every fourth gap. The remaining three gaps will be filled with inert material having the same thickness (in grams per square cm) and atomic composition for each element present in the TMP boxes (e.g. with CH2 substituting for TMP). While the contribution of sampling fluctuations to the resolution will approximately double as a result, it is easy to show that the measured e/h must be exactly the same as for a fully instrumented calorimeter.

Request to Fermilab

At this early stage, our needs are negotiable and can be molded to fit various realities at Fermilab. At this point we can identify requirements in the following areas:

- At least three calendar months of time set up in a beam; at least 400 hours of beam illumination, not all at once; and at least 200 hours during which we may control the beam polarity, momentum, and intensity. Exclusive of Fermilab supplied counters, our equipment would occupy a beam area perhaps 20 ft long x 10 ft wide.

- Negative beam with average yield > 10 Hz of electrons or pions having energies from ten(s) to hundred(s) of GeV. To check that e/h is not strongly energy-dependent, we plan to vary the beam momentum over 1 to 1-1/2 orders of magnitude.

- Electron tagging capability, e.g. by means of a threshold gas Cherenkov counter, operable with reasonable efficiency over the beam momentum range. Also required is minimal (<0.2 radiation length) material upstream, for the portion of the run in which we have control of the beam.

- Enough beam MWPC's to define the incident particle's trajectory, and one or two beam MWPC's downstream of the test calorimeter to define outgoing beam muon tracks.

- Sufficient fast logic to form a rudimentary trigger, based on a counter telescope and the Cherenkov counter.

- Approximately 384 channels of CAMAC ADC's, and a small number of other CAMAC TDC's, etc.

- A CAMAC based data acquisition system, with a Jorway 411 and a Fermilab supplied and maintained minicomputer. At this stage of discussion, a solution involving either a MicroVAX running VAXONLINE or a PDP/11-34 running RSX MULTI/DA seems viable, although the former might be easier to maintain and use. Appropriate disk(s), tape drive(s), and terminals would also be needed. The data acquisition rate would be low, <10K bytes/sec.

Possible locations for the test

We have considered four possible locations for this test, which we list below with comments on issues needing further examination.

(1) Beamline NT, in Lab F or Lab E. A possible issue is competition for beam time with the muon bubble chamber and ZEUS test runs.

(2) Beamline NE, in Lab G or Lab D. Availability of real estate in Lab G depends, in part, on the future location of E690. Real estate in Lab D depends, in part, on the future of E653 and its

possible descendants. Both threshold and differential Cherenkov counters are available in beamline NH (which will not be running) and can be moved to beamline NE.

(3) Beamline NA, in Lab NWA. Real estate is scarce, especially if magnets are added in NWA to enhance the low-energy electron flux. Competition for running time with the D-Zero test program would be an issue.

(4) Beamline MT. Competition for running time with the extensive CDF calibration program would be an issue.

Basis for possible approval of this test

We ask that Fermilab support this test on the basis of its (detector) physics interest. Funding for SSC/LHC detector development is impossibly tight in FY88, especially in relation to the enormous experimental challenges involved. We cannot proceed with a 1989 test if we must provide support for items that would normally be made available at Fermilab to a typical small experiment.

References

[1] R. Wigmans, CERN/EF 86-18, CERN/EP 86-141 (1986), and private communication.

[2] B. Aubert et al., "Fast Hermetic Calorimetry Using Warm Liquids: Proposal for Generic Detector R&D for the SSC/LHC" (September 1987). Attached as Appendix A.

[3] UA1 Collaboration, "Design Report of a U-TMP Calorimeter for the UA1 Experiment with ACOL", UA1 TN/86-112 (1986).